Detailed Comments
A. Review of BTeV Physics Case

While the Committee believes that BTeV presents the opportunity for a broad program of B physics, it is also true that certain processes have a particularly important role to play both in the extraction of fundamental physics and in the decision of whether the proposal will be approved. These processes are those which are theoretically clean or particularly useful for comparing the performance of BTeV to competing experiments, such as LHCb. We will focus here on the modes $B \to \rho\pi$, $B_S \to D_S K$, $B \to D^*\rho$, $B \to J/\psi K_S$, $B^- \to DK^-$, and $B_S \to D_S\pi$ (for the measurement of x_S). In the Committee's opinion, a full GEANT simulation of the first three is desirable, whereas a thorough study based on MCFast should suffice for the others.

The Committee notes that BTeV's analyses of these modes are based on the common assumptions of a luminosity of 2×10^{32} cm^{-2}sec^{-1} and 10^7 sec of running time.

The physics simulations presented in the PTDR are based on the simulation package MCFast. The collaboration has used this package to model and incorporate a wide variety of important physics and detector effects, such as the resolution of the pixel detector, the effects of multiple interactions per crossing (expected to be two, on average), and the response of the electromagnetic calorimeter. Although it is clear that the collaboration will continue to rely on MCFast for most of its simulation effort, the Committee looks forward to full simulation of a few fundamentally important processes and their backgrounds.

The asymmetry in the decay $B \to J/\psi K_S$ provides a theoretically clean determination of the CP violating angle β. BTeV has studied the time-integrated asymmetry in the decay chain $B \to J/\psi K_S \to \mu^+\mu^-\pi^+\pi^-$. Impact parameter cuts are used to reject the large background from prompt J/ψ's and K_S's. The total εD^2 is estimated to be 10%, from a combination of jet charge, lepton, and kaon tagging. In a year of running, BTeV expects to reconstruct 109,000 events with S/B=10, leading to an uncertainty in $\sin2\beta$ of 0.021 from the time-integrated asymmetry. Although the collaboration notes that a study of the time-dependent asymmetry would improve the accuracy of this measurement, they have not yet done one. The Committee encourages BTeV to conduct such a study in the next year. The Committee would also like to see a more detailed study of tagging efficiencies both for B's and for B_S's.

Because of their excellent electromagnetic calorimeter, $B \to \rho\pi$ is a mode in which BTeV has an opportunity to be substantially better than LHCb. It is also particularly important, since at this time a Dalitz plot analysis of this decay holds the best promise for a theoretically clean extraction of the CP violating parameter α. At this point, the studies of this mode are quite preliminary, consisting only of an estimate (2800) of the number of reconstructed events per year, with no attempt to include backgrounds. In the view of the Committee, it is extremely important that BTeV improve this analysis substantially in the next year. Not only is this mode important for its own sake, but it provides a concrete situation in which the experiment can evaluate its ability to use its excellent calorimeter to do a complicated physics analysis which includes π^0's. The Committee is particularly concerned that the large number of background π^0's from the underlying events be accounted for and rejected in a realistic way. The Committee is very interested to see a convincing statement of the uncertainty in sin 2α which could be expected from BTeV.

The time-dependent asymmetry in the decay $B_S \rightarrow D_S K$ could provide a theoretically clean measurement of sinγ. The precise sensitivity of the analysis will depend on a currently unknown ratio ρ of strong interaction matrix elements (which will be extracted from the analysis) and on the value of x_S. BTeV has estimated that with x_S=20 and ρ=0.5, their uncertainty on γ will be approximately 10° based on 2680 tagged events in one year. Since the final state must be distinguished from $D_S\pi$, which has a branching ratio fives times larger, excellent particle identification is crucial here. The Committee believes that a more detailed simulation of K/π separation for this measurement is needed. The treatment of backgrounds also is still quite primitive: a model background with exponential time dependence is simply folded into the extraction of γ from the probability function. The Committee believes that a complete analysis of the physics backgrounds is necessary before a realistic assessment can be made of BTeV's reach in this mode.

It is also possible to measure sinγ cleanly from the asymmetries in the decays $B^- \rightarrow DK^-$, if two different decay modes of the D are analyzed simultaneously. This analysis has the advantage that it requires neither tagging nor time-dependent measurements; on the other hand, the sensitivity depends on unknown B and D branching ratios. With a set of reasonable assumptions, BTeV claims to be able to measure γ with a statistical error of approximately 13° in one year of running, based on 320 events in the channel $D \rightarrow K\pi$ and 1600 events in the channel $D \rightarrow K^+K^-$. However, the analysis in the PTDR contains no discussion of backgrounds. The Committee believes that a complete analysis is necessary before one can judge realistically the sensitivity in this mode.

The quantity x_S is important for its own sake, although an accurate measurement will probably already be available by the time that BTeV starts taking data. It is also useful as a benchmark for assessing the experiment's ability to integrate its capabilities in proper-time resolution, tagging, and particle identification, as well as its overall sensitivity to B_S physics. BTeV claims a reach in x_S of approximately 60 in the $D_S\pi$ mode, based on 16,100 events reconstructed. In this case, the Committee is pleased to see that the discussion of both the analysis and the backgrounds is much more complete and realistic. This sets a standard which the Committee believes must be met by the collaboration for the analyses of the other modes discussed above.

The Committee was pleased to see results from a preliminary study of the mode $B \rightarrow D^*\rho$, which demonstrated BTeV's reconstruction capability. We would welcome a followup study based on full Monte Carlo simulation.

B. Review of BTeV Pixel R&D

The pixel system is one of the most ambitious components of BTeV, and it is the most critical to the success of the experiment. Impressive progress has been made over the past year, but a vast number of issues must be resolved before this system can be built. The system is highly complex, comprising five major components: the sensors, the readout chips, the control chips and associated high-density connections, the mechanical support and cooling system, and the data transmission to the first-level trigger.

With regard to the sensors, BTeV is collaborating with US-CMS and has taken advantage of ATLAS pixel designs. In addition, BTeV has an active program to develop detailed computer simulations of the sensors to understand issues related to the electric field map, charge collection, $\overline{E} \times \overline{B}$ effect, resolution, etc. Nevertheless, there is a very large amount of remaining R&D associated with designing rad-hard sensors. The Committee encourages BTeV to evaluate designs using a smaller number of sensors to reduce the cost and complexity of the system. In addition, BTeV is investigating diamond pixel detectors and oxygenated silicon wafers produced by other groups. It is important that BTeV develop an efficient and systematic approach to these issues.

The work on fine-pitch bump bonding appears promising, and the Committee notes BTeV's careful approach to multiple vendor evaluation using dummy modules that can be electrically tested. Still, there is much more work to do here in determining the yield from different vendors and in establishing a reliable production line. The Committee notes that the original R&D plan called for a "decision on sensor material and implant type by June 1999" and a "final BTeV sensor specification by May 2000."

Test results on the FPIX0 and FPIX1 readout chips bonded to sensors are encouraging. A major decision remains as to which rad-hard technology will be used. The Committee looks forward to hearing the results on upcoming beam tests to evaluate the performance of hybridized pixel detectors. The Committee would like to understand better to what extent the FPIX1 chip meets the actual readout and trigger requirements and what types of improvements in the readout chip design are planned.

The Committee notes that the original R&D plan called for an RF shielding solution by the end of 1998. Although work in this area has begun, the preliminary TDR states that a two-year effort will be undertaken, involving tests using Roman Pots at the Tevatron. The Committee would like to better understand this program of measurements.

The BTeV response to questions posed by the PAC in May 1999 states (p. 7) that "the choice of the number of pixel planes per station and of the detailed configuration of the forward tracker depend on the level of background in the experiment, which can only be determined by actual measurements in C0." This response also states (p. 4) that little progress was made on simulation studies of beam-related backgrounds: "To proceed, we need a reasonably detailed model of the interaction region magnetic elements, collimation, and shielding which is not currently available to us." The Committee is unclear as to BTeV's overall goals and plans for measuring and simulating beam-related backgrounds. The Committee would like to know how such backgrounds could influence the design of the detector and on what time scale the information is needed. It is also unclear to us whether meaurements performed in C0 next year would reflect the actual conditions during BTeV running.

Overall, the Committee is impressed with recent progress on the pixel system. The Committee is concerned, however, that while there is good progress on the design of the components with respect to electrical performance, very little effort has gone into producing an integrated low-mass mechanical, electrical, and thermal design. Such a design might reveal the need for modifications to components which might otherwise appear satisfactory from the electrical engineering point of view. Given the complexity of the pixel system, the Committee encourages BTeV to push towards a system prototype that would test not only the electrical performance, but also the mechanical and thermal properties.

C. Review of BTeV Trigger

The goal of the BTeV trigger is to reconstruct tracks and find vertices in every interaction, up to a luminosity of $2x10^{32}\ cm^{-2}s^{-1}$. This goal should be achieved using tracks emitted at angles smaller than about 10^{o} with respect to the Tevatron Collider beams. A background rejection of a factor of 100 or more should be obtained at Level 1, in a deadtimeless mode with 132 ns interbunch spacing. This is a very ambitious plan indeed: the collaboration is urged to exert the maximum caution and realism when developing and testing this trigger. The collaboration is correct in emphasizing the importance of the trigger. The Committee is not yet convinced, however, that it will perform as advertised

The planned Level 1 trigger is based on a highly parallel architecture of fast processors that exploit tracking information primarily from the silicon pixel telescopes. Track segments are first formed in each pixel station, which in the baseline design contains three planar pixel arrays. This is done in parallel in narrow azimuthal detector slices in order to reduce the number of combinations to be examined, and therefore, the processing time and the number of fakes. Primary event vertices are then constructed in a common main station, and tracks missing them are identified. When two or more tracks are not associated with a primary vertex, a Level 1 accept is generated. The operation of this trigger has been extensively simulated. It is claimed that the complication of multiple event vertices can be handled, up to 3 vertices per bunch crossing. The Committee believes that the successful operation of the detached track trigger in multiple vertex events remains to be demonstrated fully. Results of the first studies are encouraging, but this is a delicate problem, since tracks could easily be associated with the wrong vertex when multiple vertices appear in the same bunch crossing. The Committee requests that careful study of this problem be continued, and that the effect of potential beam misalignments also be considered. The efficiency of triggering on a beauty event is 40% or more for a number of interesting decay channels. The rate of spurious triggers by minimum bias events can be reduced by the desired factor of 100 up to a luminosity of $2x10^{32}cm^{-2}s^{-1}$. The importance of these studies should not be underestimated. They should be continued and refined to correspond more precisely to the experiment hardware and trigger software.

Trigger studies have been extended to simulate the acceptance rate of a simplified pixel detector, with two pixel planes rather than three per station.

Rejecting the combinatorial background when creating track segments implies, in this case, checking the hit alignment in at least three stations. Even if fast coding languages are adopted, the time needed for finding segments and linking them into tracks is a concern. On the other hand, reducing substantially the thickness of the pixel stations, as well as that of the straw tube forward tracker, is deemed to be important in order to reduce the secondary interactions in the detector to a tolerable level.

The beam-associated background is another reason for concern, since it depends on machine losses that cannot be easily predicted. In particular, it should be noted that the halo accompanying the outgiong beam hits the detector coincident with the interaction products and therefore cannot be discriminated by timing. Presently there is no real proof, even at the simulation level, that a detector with reduced material can work at the specified performances.

It may be desirable to test a detector slice implemented with the real trigger hardware in a beam. It is not clear to the Committee, however, whether it is feasible to plan for such a measurement in the forthcoming set of test beam measurements of BTeV detector components in 1999. Someday, a test at C0 might be able to simulate the background conditions.

Only three drift tube tracking stations are planned in the muon toroid spectrometers. Despite the high segmentation into small tubes, the background of spurious tracks at such small angles downstream of the interaction point is a concern. It is important to ensure that spurious triggers will be held to an acceptable rate. A more thorough study of this problem is recommended, including use of previous experience at CDF and D0 and experimental studies during the forthcoming Tevatron Run II.

D. Review of BTeV EMCal

The Committee is pleased to see that BTeV has identified a potentially suitable technology, PBWO4 crystals, for use in the electromagnetic calorimeter. This material offers good resolution, radiation hardness and time resolution, and it has been extensively studied by CMS. The Committee recognizes that BTeV is just getting started in the design of the electromagnetic calorimeter, so the performance studies presented thus far are quite preliminary. The Committee encourages BTeV to develop a full simulation of the detector performance and to perform comprehensive studies of γ and π^0 reconstruction with realistic backgrounds. The difficulty in obtaining the required quantities of PbWO4 crystals is a very serious concern. The Committee encourages BTeV to address this issue as vigorously as possible.

E. Review of BTeV Particle ID

High-quality particle ID, primarily K/π separation, is essential for BTeV's physics objectives. This capability is used not only for reconstruction of signal modes, but also as an essential part of tagging. The relevant momentum range is quite large, extending up to about 100 GeV for the daughter particles of two-body decays such as B -> $\pi\pi$ and B -> $K\pi$. Most kaons useful for tagging are produced as secondaries from D decays, and they have a momentum spectrum that is mainly below 15 GeV, until an acceptance cutoff at 3 GeV due to the magnet.

The BTeV effort on particle ID has been directed primarily towards understanding the performance requirements with Monte Carlo simulations and developing a conceptual design drawing on experience with other recent RICH detectors. To deal with the broad momentum range, BTeV has proposed a RICH with gas radiator to cover momenta above 10 GeV and an aerogel radiator for lower momenta. For detection of the Cerenkov photons, BTeV is considering both multi-anode photomultiplier tubes and hybrid photo-diodes. BTeV has made rough estimates of the expected angular resolution on the Cerenkov rings, which indicate that the system could achieve the required performance. Granularity and number of electronics channels are important issues for performance and cost.

BTeV's RICH R&D plans for the next year are modest, focussing mainly on simulations of aerogel performance and evaluation of different photo-detector options. The Committee believes that the RICH effort should be substantially strengthened over the next year.

F. Comparison of Experiments

Hadron collider b-physics studies are being or will be carried out by CDF, D0, ATLAS, CMS and LHCb. Of these, the strongest competition to BTeV will come from LHCb. Therefore, the Committee has considered primarily the capabilities and physics reach of these two experiments. It must be understood that such a comparison is highly preliminary since neither experiment is fully designed and simulated.

In making the comparison, it is helpful to keep in mind some basic differences:

1. The experiments will operate at comparable luminosities, but the larger boost of b-hadrons at LHCb gives it a slightly greater geometrical acceptance per arm. BTeV, however, will have a double-arm spectrometer while LHCb will have a single arm. The net effect, estimated by LHCb, is that BTeV's acceptance is 1.7 times greater.

2. The b-production cross section at LHC is 5 times larger than it is at the Tevatron, while the total cross section is only 1.6 times larger. Thus, the fraction of events with a b-hadron is 3 times larger at the LHC.

3. Taking into account the different bunch crossing frequencies of the two experiments, and the fact that BTeV triggers on detached vertices at Level 1, LHCb estimates that BTeV has a 2:1 trigger efficiency advantage.

4. Other advantages of BTeV include: a PbWO4 EM calorimeter to measure γ's better; a smaller range of track momenta to be measured in the Cerenkov counters; and a vertex detector in the magnet field, making it easier to reject low momentum tracks at the trigger level.

The Committee compared the claimed reach of BTeV and LHCb for a measurement of sin2β (via B -> J/ψ Ks); xs; sin2α (via the problematical mode B -> π+ π - and via B -> $\rho\pi$ modes); the angle γ; and various rare decay modes such as B -> K*γ and B -> K*l^+l^-. With the exception of B -> $\rho\pi$, it appears that the two experiments are roughly comparable. While neither experiment has done a credible analysis of B-> $\rho\pi$, BTeV claimed (and the Committee expects) that its precision PbWO4 EMcal has the capability to give it a significant advantage for these crucial modes. It is necessary that BTeV convincingly establish this claim.